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Scanning Photoemission Microscopy of Photo-cathode Surfaces

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Abstract: *We describe a scanning photoemission microscope using a focused laser beam. We find the system can provide photoemission images with ~10μm resolution. Images of Cs deposited in local areas on clean p-GaAs showed that the Cs does not move significantly even when heated to 450C.*

Keywords: emission microscope, cold cathode; photoemission; negative electron affinity.

Introduction

Applications such as Free Electron Lasers that utilize RF accelerators to create high energy, high current electron beams require cathodes that produce extremely high peak current densities in short pulses (~10 pS) with low emittance at high repetition rates. Such short pulses are typically produced using photo-cathodes excited with mode-locked lasers. Since laser power tends to decline at short wavelengths, the photocathode should ideally operate in the visible. However, most visible photo-cathodes require extreme vacuum, which is difficult to achieve in high current guns. Photoemission using visible wavelengths requires a large surface dipole; normally created by coating the surface with a combination of electropositive (e.g. Cs) and electronegative elements (e.g. O or F). Any such dipole layer is inherently thin and reactive, and typically must be re-applied periodically. Such cathodes would be much more convenient to use if the surface dipole could be re-generated without physically moving the cathode. One suggested means of re-applying the coating is similar to a thermionic dispenser cathode or controlled porosity cathode; for example a Cs reservoir connected to the cathode surface via a porous material or set of holes that allow fresh Cs to diffuse from a backside reservoir across the surface. To make this work, the coating material should diffuse across the surface with reasonable speed and at a temperature below the point where significant evaporation or decomposition takes place. Such surface motion will depend on the specific substrate and coating.

Photoemission Microscopes

To evaluate surface motion of coating materials experimentally, we are building two types of photoemission microscopes. One type uses electrostatic lenses to image the electron distribution created at the cathode surface onto a phosphor screen. This approach can provide real-time images with spatial resolution less than 100 nm and may include an energy filter. We are building a UHV chamber including a commercial version of this microscope, custom manipulator, load lock, deposition, and surface analysis tools, the design is shown in figure 1.

The other microscope (figure 2) images by scanning a focused laser beam over the surface; this microscope's resolution is limited by the focal spot size (~10 μm) and the data acquisition time is longer (minutes), but larger areas can be imaged and the specimen surface is accessible during the measurement. Our microscope consists of a laser and microscope mounted on a UHV chamber via a computer-controlled scanning stage, and includes a load-lock, specimen heater (800 C), Cs source, and manipulated probe wire. Cs coatings can be patterned using shadow masks.

Experiment

We deposited Cs onto GaAs and silicon surfaces through a shadow mask. These surfaces produced images similar to figure 3. The images show areas of high photoemission current corresponding to the areas where Cs was deposited. However, the cesiated areas were not sharply defined. This may be caused by the large deposition angle (close spacing between the Cs source and the surface, large Cs source), some initial mobility of the Cs on the surface, or poor initial adhesion. However, once the deposition was over, the Cs showed no measureable diffusion. The Cs remained adsorbed on p-GaAs at temperatures up to 450C, but showed no detectable movement (moved less than ~20 μm). Additional experiments using a silicon wafer fragment as a contact mask on Si produced a sharper Cs boundary, but also failed to detect any Cs motion on silicon.

Summary

These initial experiments indicate that elemental Cs does not move across silicon or GaAs surfaces far enough to be measured with this resolution. However, if motion occurred over distances less than the experimental resolution, it might still be adequate. We plan to use the PEEM to make higher resolution measurements. Using other semiconductors or adding other elements at the interface may also improve the surface motion.

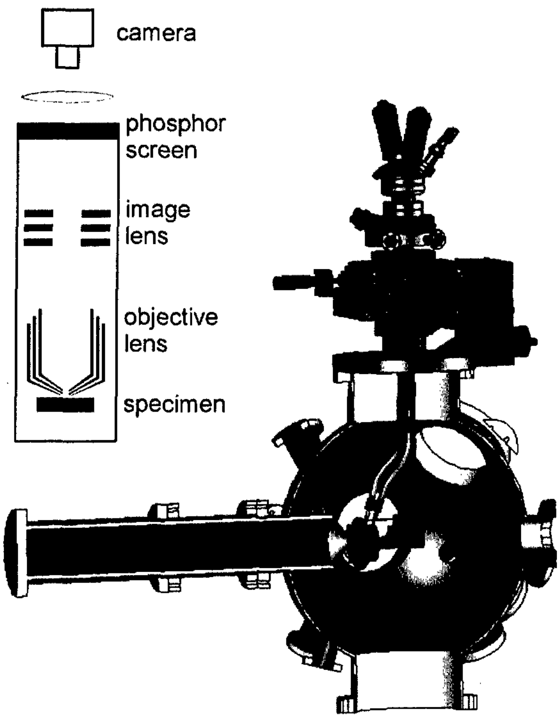


Figure 2. Cutaway view of the planned PEEM chamber showing the specimen manipulator and PEEM head. The specimen must be placed 2μm $^{+}/_{-}$ 0.01μm from the first PEEM lens aperture. The inset shows a simplified schematic of the PEEM imaging lenses. The chamber will also contain a standard electron energy analyzer for Auger and photoemission spectroscopy, low energy electron diffraction, and ports to allow surface cleaning and coating.

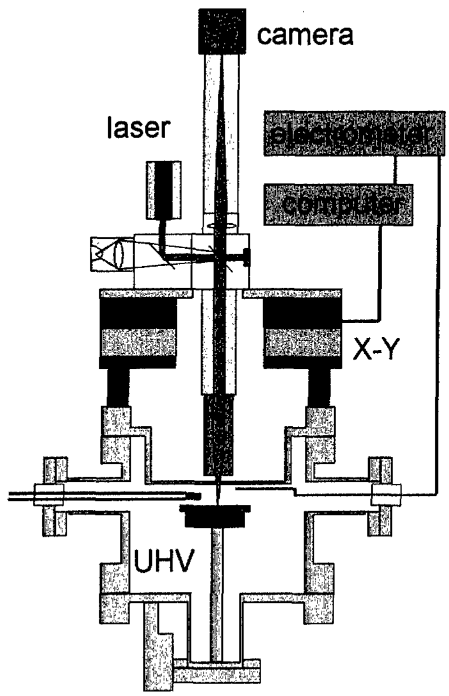
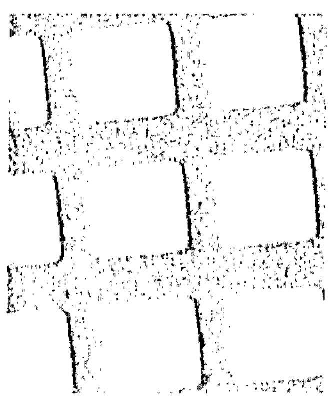


Figure 1, Scanning photoemission microscope schematic



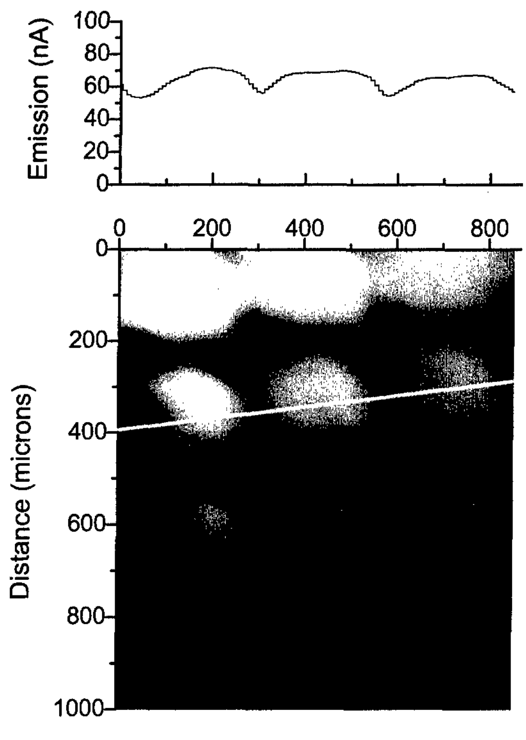


Figure 3. Photoemission data obtained from a GaAs surface after Cs was deposited through a shadow mask. Left: optical image of the shadow mask. Top: emission current as a function of position along the line in the bottom plot. Bottom: Photoemission data displayed as an image.